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Testing and Evaluation of Chemical Warfare Agent Detectors — Code of Practice

ICS 13.320

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

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Chemical Hazards Sectional Committee, CHD 07

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Chemical Hazards Sectional Committee had been approved by the Chemical Division Council.

Among the Weapons of Mass Destruction (WMD), Chemical Warfare Agents (CWAs) are probably one of the most brutal created by mankind. CWAs are extremely toxic synthetic chemicals that can be dispersed as a gas, liquid, aerosol or adsorbed to particles to become a powder. These CWAs have either lethal or incapacitating effects on humans. Thousands of toxic substances are known, but only some of them are considered as CWAs based on their characteristics, namely, high toxicity, imperceptibility to sense and rapidity of action after dissemination, and persistency are listed as scheduled chemicals in the Chemical Weapons Convention (CWC).The CW agents possess different characteristics and belong to various classes of compounds with pronounced physicochemical, physiological and chemical properties. Thus, they are classified in many ways. Based on their volatility, they are classified as persistent or non-persistent agents. The more volatile an agent, the quicker it evaporates and disperses. The more volatile agents like chlorine, phosgene and hydrogen cyanide are non-persistent agents whereas the less volatile agents like sulfur mustard and VX are persistent agents. Based on their chemical structure, they can be classified as organophosphorus (OP), organosulfur and organo fluorine compounds and arsenicals. In general, classification in terms of physiological effects produced on humans by the CW agents is used for many decades. Thus, the CW agents used in warfare are classified as follows:

a) Nerve agents;
b) Vesicants (blistering agents);
c) Bloods agents (cyanogenic agents);
d) Choking agents (pulmonary agents);
e) Riot-control agents (tear gases);
f) Psychomimetic agents; and
g) Toxins.

The purpose of detection and alarm system is to detect CWAs at the earliest practicable manner and to give an alarm so that appropriate protection and medical counter measures can be taken up. The general principles given below are for guidance to design and develop detection and alarm system. The CWAs detection system should have following characteristics;

a) Detect quickly enough to fulfill its intended functions.
b) Detect, semi-quantify and warn personnel of the presence of vapor or gas phase CWAs.
c) Visual and audible indicators and alarms.
d) Display the class of CWA.
e) Reliably transmit the detection signal and made available locally and for transmission to a remote location to a certain range.

Testing and evaluation of chemical detectors for detection of CWAs and its simulant is a very sensitive and specialized subject. Performance evaluation of Chemical Warfare Agent Detectors (CWADs) is carried out by assessment of the performance of the detector in the simulated test environment which is created by CWAs vapor generation. In the laboratory conditions, the test environment for the test and evaluation of detector is created by generation of definite concentration of a particular agent under specified temperature and humidity conditions. The outcome of the testing will ensure the performance of a chemical detector in the field conditions. The considerable assistance has been provided by DRDE, Gwalior in the development of this standard.

This standard describes about the test and evaluation procedure for chemical warfare agent detectors. It includes the procedure for CWA vapor generation, sampling, quantitative analysis and testing at various combinations of humidity and temperature.

(*Continued on third cover*)

Indian Standard

TESTING AND EVALUATION OF CHEMICAL WARFARE AGENT DETECTORS — CODE OF PRACTICE

1 SCOPE

1.1 This Indian Standard covers the detailed procedures for the testing and evaluation of point and stand-alone Chemical Warfare Agent Detectors (CWADs).

1.2 This standard covers testing and evaluation of CWAD with selected live CWAs at Joint Service Qualitative Requirement (JSQR)/Acceptance Test Procedure (ATP)/Trial Directive specified challenge concentrations. The list of selected live CWAs and their JSQR specified challenge concentration as specified in Table 1. Other live CWAs will not fall under the scope of this standard.

Table 1 Chemical Warfare Agents and their JSQR Specified Concentrations

(*Clause* 1.2 **)**

Sl No.	**Agents**	**Concentration, mg/m^3 (Tolerance Upto + 25 Percent)**
(1)	(2)	(3)
i).	**Nerve Agents**	0.05 mg/m^3
	i) Tabun (GA),	
	ii) Sarin (GB),	
	iii) Soman (GD),	
	iv) Cyclosarin (GF); and	
	v) VX.	
ii)	**Blister Agents**	0.5 mg/m^3
	i) Sulphur mustard (HD); and	
	ii) Lewisite(L).	
iii)	**Choking Agents**	20 mg/m^3
	i) Phosgene (CG)	
iv)	**Blood Agents(AC)**	20 mg/m^3
	i) Hydrogen cyanide (HCN)	

1.3 This standard also covers vapor generation procedure of selected live CWAs (as stated above) which will be used for the performance evaluation of Chemical Agent Monitor (CAM) and Automatic Chemical Agent Detector and Alarm (ACADA) CWAD, detailed procedures for sampling of generated CWAs vapor and their quantification.

1.4 This standard shall be used for the test and evaluation of CWAD at different combination of humidity and temperature at applicable JSQR/ATP/Trial directive level of CWA challenge concentration.

1.5 It also describes about the potential interferents of various category to be tested in the test and evaluation of CWAD.

1.6 This standard does not cover any information regarding Toxic Industrial Chemicals (TICs) and Toxic Industrial Materials (TIMs).

1.7 This standard does not cover all the associated safety concerns for handling and generation of toxic CWA. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

1.8 Nothing in this standard prevents to have higher level of protection for handling of CWAs.

2 TERMINOLOGY

For the purpose of this standard the following definition shall apply.

2.1 Adsorption — A surface phenomenon in which atoms, ions or molecules are concentrated on a surface by chemical or physical forces, or combination of both.

2.2 Challenge — The process of exposure of Chemical Warfare Agent Detector (CWAD) at outlet of vapor generator for testing.

2.3 Chemical Warfare Agents (CWAs) — The CWA is a chemical substance whose toxic properties are used to kill, injure or incapacitate human beings at a very low level of dose.

2.4 Chemical Warfare Agent Detector (CWAD) — The CWAD is a device to detect and warn the concern personnel about the presence of CWAs in form of vapor and aerosol.

2.5 Calibration — The set of operations that establish, under specific conditions, the relationship between values indicated by a measuring instrument or system and the true values.

2.6 Chromatography — A technique for the separation of a mixture of components. Mixture passed through a medium in which the components move at different rates.

2.7 Confidence Check — It is a functional test with confidence sample (given by company) or with simulant to ensure its functionality prior to actual challenge.

2.8 Decontamination — The process of making any person, object, or area safe by removing contamination by physical or chemical means.

2.9 Desorption — It is reverse process of adsorption i.e. elimination of adsorbed species from the surface of adsorbent.

2.10 Detection — The act of sensing of the surrounding atmosphere specifically to identify the presence of CWA vapors, aerosol or gas.

2.11 Failure — The event in which detector does not perform one or more of its required functions.

2.12 False Alarm — The condition in which the CWAD indicates the presence of CWA or simulant when none is present (false positive) or a condition in which CWAD indicates the absence of CWA or simulant when the live CWA or simulant is present (false negative).

2.13 Functional Acceptance Tests — Tests performed to determine that an instrument is operational and capable of performing its intended function.

2.14 Interferents — Any substance whose presence interferes with an analytical procedures and generates incorrect results.

2.15 Linearity — It is defined as the concentration range over which the CWAD response is linearly proportional to the concentration of the CWA in the sample.

2.16 Operational Mode — The state of the detector after power up and initialization when air sampling, analysis and detection are possible.

2.17 Peak Area — The area of a peak is proportional to amount of the compound that is present. The size of the peak area is nearly equal to the quantity of the substance present in the mixture.

2.18 Range — It is the analyte concentration values between the lowest (limit of quantification) and high limits (limit of linearity) within the assay range, linearity, accuracy and precision are acceptable.

2.19 Response Time — Time taken by CWAD in order to respond and indicate an alarm after exposing to CWA.

2.20 Recovery Time — Recovery time is defined as the time required for the output signal of the detector to return to a zero baseline after exposure to the CWAs.

2.21 Retention Time — It is a measure of the time taken for a solute to pass through a chromatography column in GC analysis.

2.22 Sensitivity — It is measure of CWAD ability to determine the lowest concentration of chemical agent with certain confidence level.

2.23 Simulant — Chemical compound that contains similar physico-chemical properties of CWA, often used to safely challenge a detector and verify or test detection capability or accuracy, or both.

2.24 Specificity — Specificity is the ability of CWAD to assess unequivocally the targeted chemicals in a sample containing components which might be expected to be interfering.

3 SYSTEM REQUIREMENTS

3.1 Operational Concept

3.1.1 The CWAD will provide emergency response to the personnel and may be based on various principles and configurations. They can be configurable into four operational modes: personal, fixed installation, vehicle-mounted and chemical survey detector.

3.1.2 The CWAD will be used by the first responders for monitoring interior or exterior spaces, vehicles, and other appropriate structures to determine the contamination.

3.1.3 Since, CWAD is a vapor detector, it may not detect chemical agents in solid/liquid form below their vaporization level. However, once the solid/liquid agent reaches its vaporization level, CWAD will be able to detect the agent (at designated concentrations).

3.2 Functional Characteristics

The CWAD will accommodate each of the functional modes as specified in Table 2.

4 SAFE HANDLING AND DISPOSAL/DECONTAMINATION OF CWAS

Chemical warfare agents are extremely hazardous and lethal compounds. They should only be used in designated laboratories by personnel trained in safe-handling and decontamination procedures and with immediate access to medical support. Safety and standard operating procedures must be developed and approved before any chemical warfare agents are handled. Chemical warfare agents can only be safely handled in laboratory chemical hoods with a minimum face velocity of 100 linear ft/min equipped with emission control devices that limit exhaust concentration to below 0.0001 mg/m^3. Individual Protective Equipments (IPE) (Nuclear Biological Chemical (NBC) suit, gloves, over-boots, NBC respiratory mask, NBC canister) must be worn for protecting against chemical hazards. Sufficient decontaminant to destroy all chemical warfare agents being handled must be on hand before commencing operations. It is responsibility of all users to follow the good laboratory practices while handling the CWAs in the laboratory.

Table 2 Functional Modes

(*Clause* 3.2)

Sl No. (1)	Functional Modes (2)	Description of Functional Modes (3)
i)	Setup	The CWAD is mounted in the position from which it will operate.
ii)	Initialization	The initialization mode is comprised of warm-up and self-test and diagnostics.
iii)	Warm-up	The operator activates the CWAD. The CWAD responds to and acknowledge the operator commands. This will continue till its stabilization.
iv)	Self-test and diagnostic	The self-test and diagnostic functions are automatically performed. If the CWAD passes, it proceeds to the operational mode. If it fails, the failure shall be identified either on the display or within the data stream. If possible, the operator or maintainer will perform corrective maintenance or repair, or submit the CWAD for repair at a maintenance facility.
v)	Operation	In the operation mode, self-test and diagnostic is performed periodically. In the operation mode, the operator may conduct a confidence check using a simulant to verify detector operation. After a successful initialization, the system automatically samples the surrounding air to detect CWA class at concentration specified in respective JSQR as mentioned in Table 3. If agent is detected, the system will alarm. When the agent concentration falls below the detector alarm thresholds, the system will automatically stop alarming.
vi)	Upload/query	The CWAD is controlled through the data port by an external system: software updates may be uploaded, stored data downloaded, and functions identified.
vii)	Off	In the off mode, the CWAD is inactive and requires further action by the operator to proceed into another mode. Recharging of the internal power source from an external power source is permitted in the off mode.
viii)	Transport and long-term storage (non-operational)	The CWAD is powered down, power source removed, with all of its external connections for communications, and is detached from other accessories. The system is not operational and is in its transport case.
ix)	Storage (short-term, operational or less than three months, nonoperational)	The CWAD is powered down and power source and required accessories installed.

Blister and nerve agents can be destroyed using saturated methanolic solutions of sodium or potassium hydroxide. HCN waste shall be disposed of into waste containers specifically designated for HCN. Waste materials may include used gloves, pipette tips, paper towels that have been contaminated with HCN. All waste containing cyanide should be collected and kept at a basic *p*H (≥ *p*H 10) to prevent the generation of hydrogen cyanide.

Ammonia cylinder shall be readily available for the neutralization of phosgene gas if any.

5 PROCEDURE FOR CWAS VAPOR GENERATION

The generation of CWA vapor depends on physico-chemical properties of the CWAs. Hence, the conditions for the generation of CWAs vapors at various combinations of temperature and humidity will be different.

5.1 Reagents

5.1.1 *All CWAs,* shall be of > 95 percent purity (purity determined with ^{1}H-NMR or GC-MS), sodium cyanide (NaCN) > 97 percent purity and sulphuric acid (H_2SO_4) > 95 percent purity

5.1.2 *Silica Gel Blue (Indicating Type)*

5.1.3 *Activated Granular Carbon Surface Area > 200 m*^{2}*/g.*

5.1.4 *Ammonia Solution (28 - 30 Percent).*

5.1.5 *Electrochemical/Metal Oxide/MS/PI/FP/IMS Detector.*

5.2 Apparatus

5.2.1 *Test Setup for the Generation of Nerve and Blister Agents*

The set up comprised of the following components:

5.2.1.1 *Activated carbon filter* — Filtering material 10 kg, filtering capacity 500 l/h.

5.2.1.2 *Liquid injection unit* — Comprising calibrated 1/10 µl syringe or as applicable, calibrated syringe pump with 0.1 µl/h or as applicable injecting capacity, agent vaporization interface and heater rod with control unit.

5.2.1.3 *Gas dilution unit* — With calibrated mass flow controllers/flow meters of various ranges, humidifying, dilution units and three-way magnetic valves.

5.2.1.4 *Pressurized air source (zero air, hydrocarbon contamination < 0.1 ppm)* — An oil-less piston air compressor or pressurized synthetic air cylinder with suitable pressure reducers and air humidity dryers.

5.2.1.5 A shut-off and pressure control valve from a compressed air source.

5.2.1.6 The schematic representation of nerve and blister agents generation assembly is given in Fig 1.

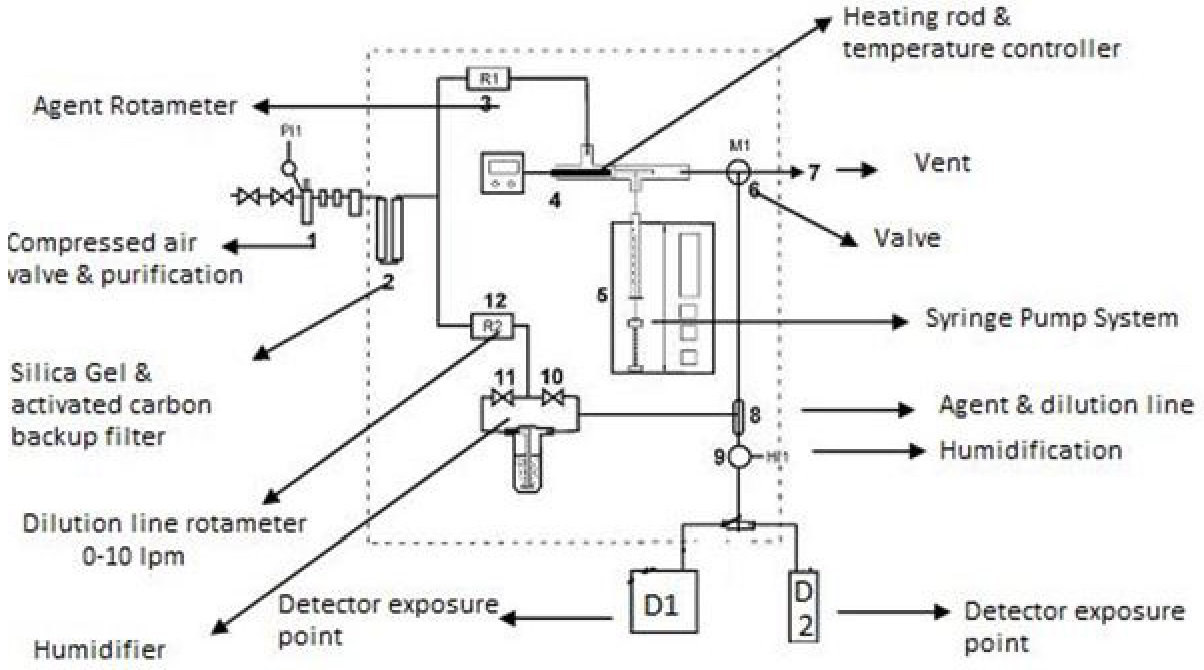
5.2.2 *Generation of CWA Nerve/Blister Agent Vapors*

Syringe drive vapor generation system is used to generate the vapors of Nerve/Blister agents. The vapor generation assembly comprises of different components as mentioned above. The syringe drive system is operated by using compressed and purified/pre-filtered air which is divided into two parts:

a) agent, and

b) dilution lines, both having their own Rota meters (Agent R1, Dilution R2 as shown Fig. 1).

The compressed air line pressure is controlled with the air filtration unit's (or pressurized air cylinder) pressure



1	Compressed air valves and purification filter system
2	Silica gel/activated carbon backup filters
3	Agent line Rota meter
4	Heater rod and temp. controller unit for agent flow heating
5	Digital syringe pump and syringe
6	Magnetic 3-way valve
7	Vent out to fume hood
8	Agent and dilution line mixing point
9	Humidity sensor
10	Humidification by-pass valve
11	Humidification valve and
12	Dilution line Rotameter

D1 and D2 are Detector attached to exposure point.

FIG. 1 SCHEMATIC REPRESENTATION OF NERVE AND BLISTER AGENTS GENERATION ASSEMBLY

control valve. The nerve/blister agent is injected slowly from the syringe into the agent vaporization interface. The syringe is pushed through the glass joint into a thin capillary tube inside the interface. The calculated quantity of nerve/blister agent is dispensed by motorized pump driven calibrated micro-syringe which diffuses/evaporates from the tip of the syringe needle into the air stream. The air with nerve/blister agent can be further diluted with a secondary air dilution line or as per requirement. The syringe flow airline, that is, agent line, should also be heated with a separate heating rod to improve evaporation rate from the tip of the syringe needle and to stop the condensation of nerve/blister agent. Final theoretical nerve/blister agent vapor concentration is merely based on the dilutent air flow rate, compound's density, molecular mass and syringe pump speed. The concentration of the nerve/blister agent is determined by offline sampling using sorbent tubes followed by GC-MS analysis.

Detailed parameters for applicable JSQR/ATP/Trial Directive defined CWA concentration is specified in Table 3.

5.2.3 *Test Set up for the HCN Generation*

The set up comprised of the following components:

5.2.3.1 *Pressurized air source (zero air, hydrocarbon contamination < 0.1 ppm)* — For example, an oil-less piston air compressor or pressurized synthetic air cylinder with suitable pressure reducers and air humidity dryers.

5.2.3.2 *Dosing pump for feeding of sodium cyanide (NaCN) and sulphuric acid (H_2SO_4).*

5.2.3.3 *Gas dilution unit* — With calibrated mass flow controllers/flow meters, humidifying and dilution units and valves.

5.2.3.4 *Glass reservoir*

5.2.4.5 *Flow meter*

5.2.3.6 *Reservoir with glass wool*

5.2.3.7 *Humidity traps*

5.2.3.8 *Silicon/rubber/teflon tubings*

5.2.3.9 *Calibrated hygrometer and thermometer.*

5.2.3.10 *Calibrated electrochemical HCN detector/metal oxide.*

5.2.3.11 *Stop watch*

5.2.3.12 *Glass column filled with glass beads*

5.2.3.13 *Mixing chamber with stirrer and stirring magnetic bar.*

The schematic representation of HCN test assembly is given in Fig. 2.

5.2.4 *Generation of Hydrogen Cyanide (HCN)*

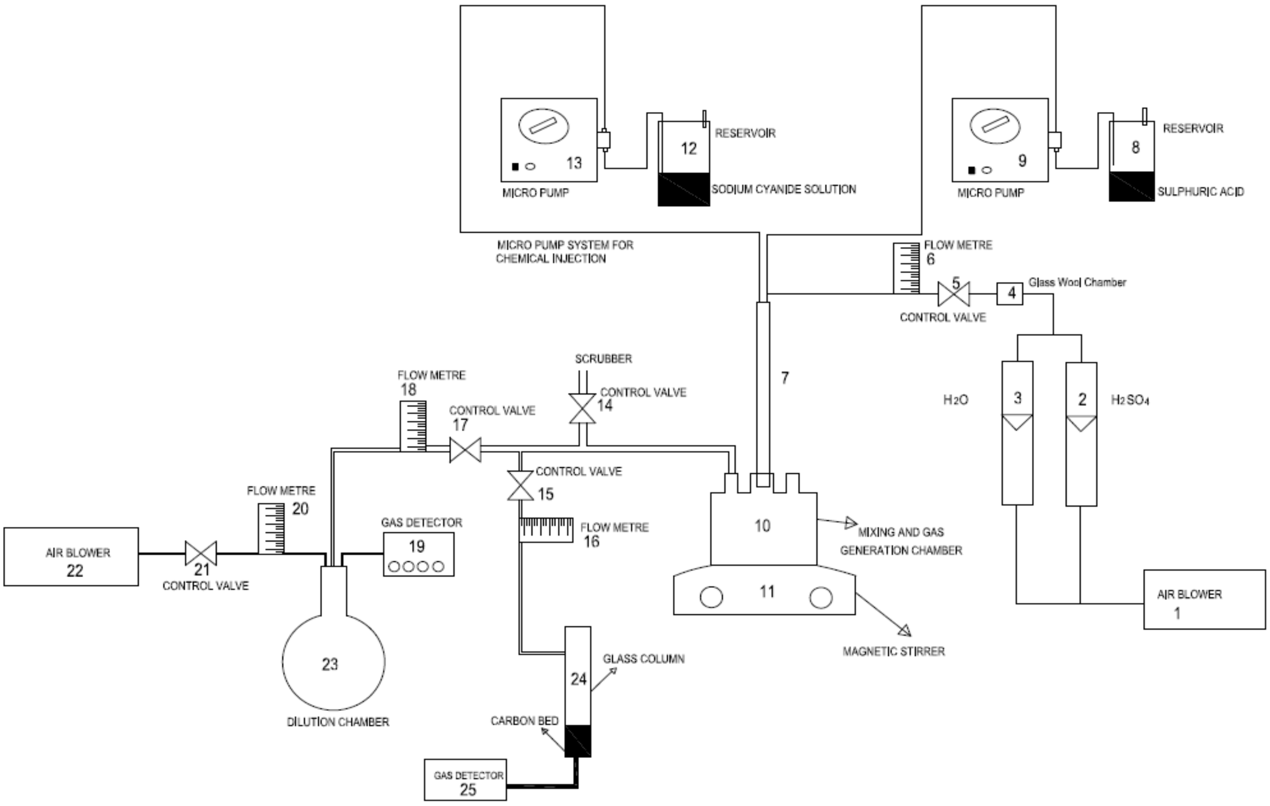
HCN gas is generated by the reaction of sodium cyanide (NaCN) and sulphuric acid (H_2SO_4) in solution phase at room temperature. Evolution of hydrogen cyanide takes place on the simultaneous addition of the NaCN and H_2SO_4. With the help of air, the produced HCN will be carried to the challenge point of detector. By adjusting the flow of feeding solutions the rate of HCN evolution is easily controlled. The required challenged concentration of the HCN gas shall be achieved by controlling the flow rate of the reactants and air. Relative humidity of HCN gas is controlled by passing the HCN containing air through water/H_2SO_4 chamber as per the requirement. The generated concentration of the HCN gas is validated using electrochemical/metal oxide HCN detector.

Table 3 Parameters for Requisite Concentration Generation

(*Clause* 5.2.2)

Sl No. (1)	Agents (2)	Concentration, mg/ m³ (3)	Volatility mg/m³ (4)	Temperature °C for Heating (5)	Agent Flow (µL/h) (6)
i)	Cyclohexyl sarin (GF)	0.05	438	100	0.01
ii)	Mustard (HD)	0.50	610	180	0.1
iii)	Sarin (GB)	0.05	16100	Not required	0.01
iv)	Soman (GD)	0.05	3.9	200	0.01
v)	VX	0.05	10.5	250	0.01
v)	Lewisite(L)	0.50	4480	180	0.1
vii)	Tabun	0.05	328	100	0.01

NOTE — Flow of primary and secondary dilution as per required concentration of CWAs.



1	Air blower	10	mixing and gas generation chamber
2	Sulphuric acid Trap	11	magnetic stirrer
3	Water Trap	12	sodium cyanide reservoir
4	Glass wool chamber	13	dosing pump for sodium cyanide
5	Control valve to control the flow	14, 15 , 17 and 21	control valve for generated HCN gas
6	Flow meter	16, 18 and 20	Flow meter of required flow capacity
7	Glass column with glass bead	22	Air blow for dilution of generated HCN
8	sulphuric acid reservoir	23	Dilution chamber
9	dosing pump for Sulphuric acid		

FIG. 2 SCHEMATIC REPRESENTATION OF HCN TEST ASSEMBLY

5.2.5 *Test Set Up for the Phosgene Gas Generation* — The set up comprised of the following components.

5.2.5.1 *Pressurized air source*, for example, an oil-less piston air compressor or pressurized synthetic air cylinder with suitable pressure reducers and air humidity dryers.

5.2.5.2 *Phosgene gas cylinder*

5.2.5.3 *Gas dilution unit*, with calibrated mass flow controllers/flow meters, humidifying and dilution units and valves.

5.2.5.4 *Control valves*

5.2.5.5 *Flow meters*

5.2.5.6 *Humidity traps*

5.2.5.7 *Silicon/rubber/teflon tubings*

5.2.5.8 *Calibrated hygrometer and thermometer*

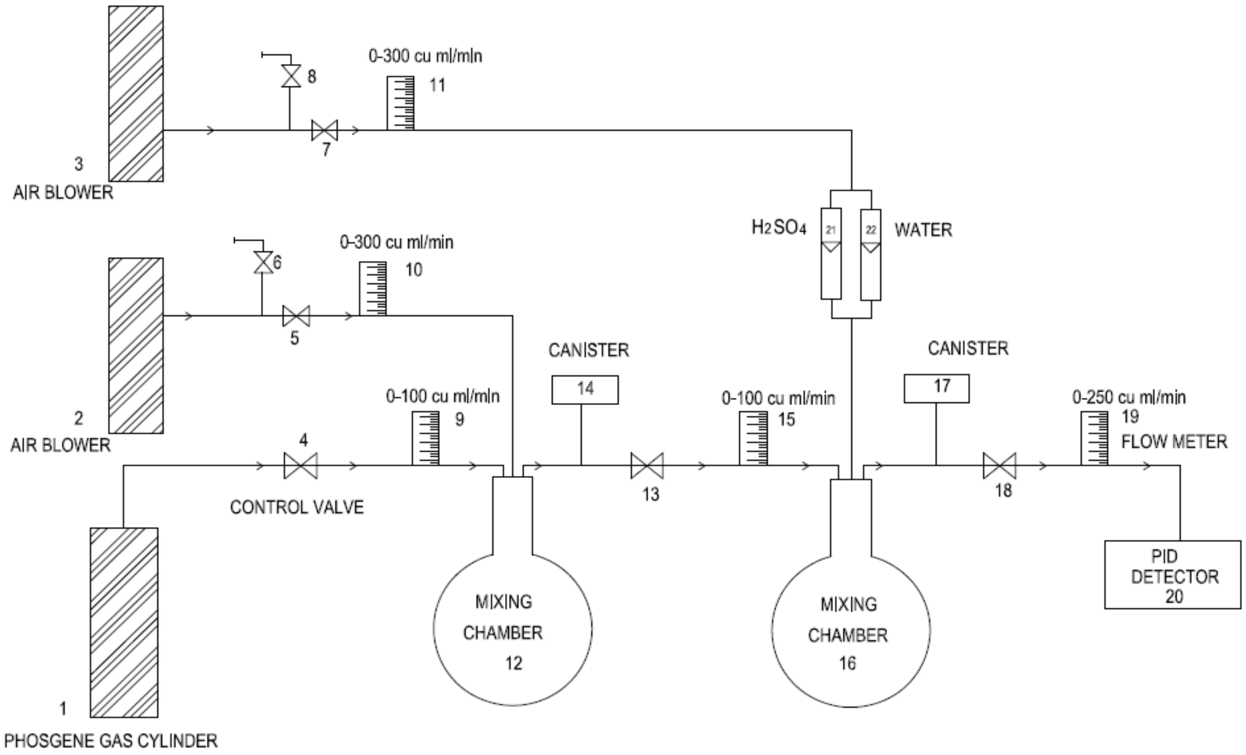
5.2.5.9 *Calibrated photoionization detector (PID) electrochemical sensor*

5.2.5.10 *Mixing chamber*

The schematic representation of phosgene test assembly is given in Fig. 3.

5.2.6 *Generation of Phosgene Gas*

Phosgene gas of the required concentration is generated by taking required amount of the phosgene gas from calibrated phosgene gas cylinder through calibrated flow meter. The phosgene gas will be diluted using air from air blower through calibrated flow meter with control valves and mixed them in a mixing chamber. The mixed air-phosgene mixture gas is further diluted (secondary dilution based on the required concentration) with air in another mixing chamber using calibrated flow meters. One portion of the generated phosgene gas is used for the evaluation of the CWA detector and other portion is passed to impregnated carbon for its neutralization. The generated concentration of phosgene is detected and measured using photo ionization (PID)/ electrochemical detector.



1	Phosgene gas cylinder	12, 16	Mixing chamber
2 & 3	Air blower	20	Phosgene detector
4, 5, 6, 7,8,13 and 18	control valve,	21	Sulfuric acid trap
9, 10, 11, 15 and 19	Flow meter	22	water trap.

Fig. 3 Schematic Representation of Phosgene Test Assembly

6 GENERAL INSTRUCTIONS FOR VAPOR GENERATION OF CWAS

Before vapor generation of CWAs ensure the following points:

6.1 Connection of flow meter should be duly inspected carefully in order to avoid any leakage.

6.2 All the tube connections shall be checked for its fitting and the exhaust tubes are directed properly into the fume hood ventilation. For safety reasons, it is recommended to place the whole vapor generation system inside the fume hood.

6.3 The fume hood ventilation should be on and all the system electrical connections should be checked.

6.4 There is enough clean, preferably de-ionized or distilled water inside the moisturizing system gas washing bottle ((30 – 40) percent of the bottle's volume is sufficient amount; do not overfill, because that may lead water droplet formation into the dilution line).

6.5 The filtration cartridges for the final cleaning and drying of the compressed air should have fresh silica gel and activated carbon (change if required).

6.6 The syringe should be clean and functional (clean with suitable solvent). Phosgene cylinder along with regulator shall be checked thoroughly for any leakage and shall be kept in separate fume hood.

7 SAMPLING OF CWA VAPORS

7.1 Sampling of Nerve/Blister Agent Vapors

7.1.1 *Apparatus*

Apparatus for sampling of nerve and blister agent vapor comprised the following components.

7.1.1.1 *Tygon/silicon/teflon tube fitting*

7.1.1.2 *Sealed sorbent tube (XAD-2)*

7.1.1.3 *Sampling pump*

7.1.1.4 *Vortex mixture for solvent extraction*

7.1.2 *Procedure for Nerve/Blister Agent Sampling*

Air sample from vapor generator is collected through a sorbent tube by using air sampling pump. Air flow through the sampling tube is adjusted/maintained stable during the sampling procedure and suitable sampling time is predetermined based on theoretical concentration inside the vapor generation system as shown in Fig. 4. The sorbent tube resin adsorbs CWA from the sample stream and after sampling the sorbent material is taken in a test tube for solvent extraction. The sampling steps include preparations, set up and sampling of vapor as given below:

7.1.2.1 Fill the trap with silica-gel/activated carbon mixture in order to purify the ambient air which will be used for the dilution of nerve/blister agents.

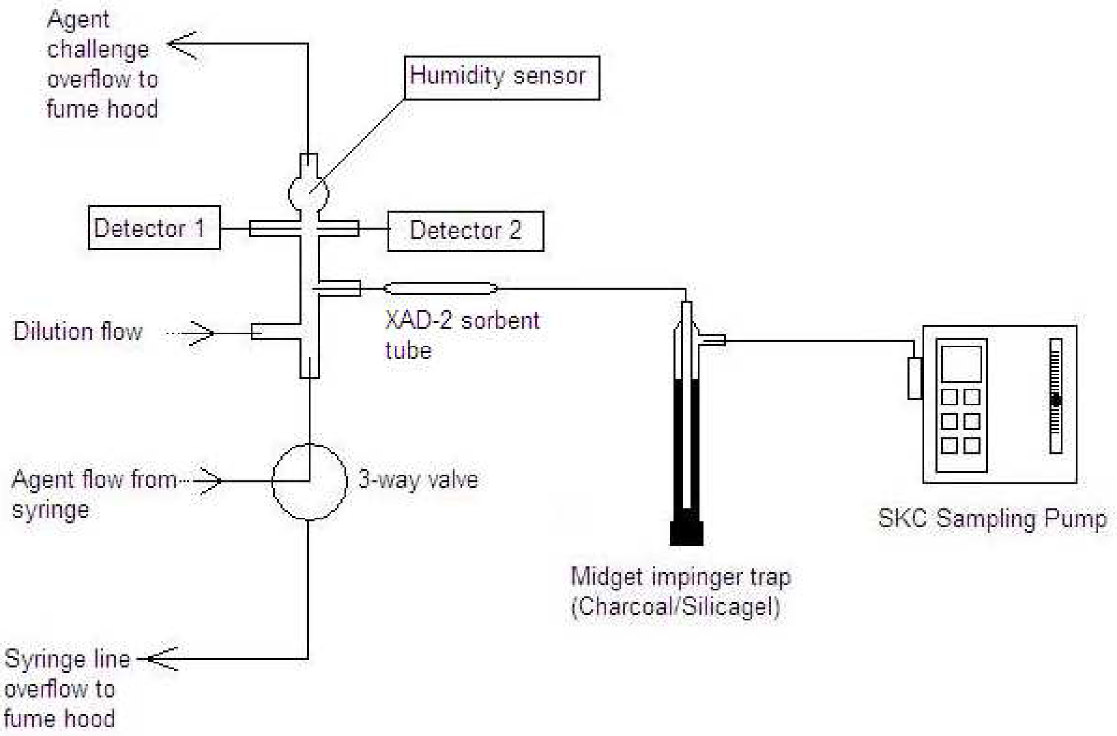


FIG. 4 SCHEMATIC REPRESENTATION FOR SAMPLING OF CWA

7.1.2.2 Take the sampling pump. Sampling pump should be checked for its operational performance prior to sampling of nerve/blister agents vapors.

7.1.2.3 Connect the inlet of sampling pump to the trap outlet by using silicon/teflon tubing.

7.1.2.4 Both the ends of sorbent tube should be broken using tip cutter. Fit the outlet end (that is, the arrow side) of the sorbent tube tightly into the sorbent trap side using silicon/teflon tubing.

7.1.2.5 Try to minimize the length between sorbent tube and Polytetrafluroethylene (PTFE) tubing by avoiding too long tubing in this position, because tubing may adsorb Nerve/Blister agents thus reducing the vapor sample recovery rate and accuracy.

7.1.2.6 Attach a screw cap with an hole septum to the vapor generator end of the PTFE tubing.

7.1.2.7 The system is now mechanically built-up for air sampling.

7.1.3 *Sample Pump Flow Setting*

7.1.3.1 Sampling pump shall be checked for its optimal flow.

7.1.3.2 As per requirement of sampling, sampling pump can be switched on/off.

7.1.3.3 Adjust the air flow using the flow adjustment control.

7.1.3.4 Use calibrated flow meter and connects its outlet tightly into the inlet PTFE tubing of the previously mentioned sampling system.

7.1.3.5 Switch on the sampling pump, for higher concentrations smaller sampling flow rates may be required to keep sampling times within minutes. Small variations may occur depending on the sample media post-sampling and analysis techniques**.**

7.1.4 *Air Sample Collection*

7.1.4.1 Connect the air sampling system with its PTFE tubing and screw cap into the side branch of the syringe drive vapor generation system.

7.1.4.2 Check that the vapor generator agent manifold valve is at "OFF" position.

7.1.4.3 Start the vapor generation with the syringe drive system and wait until the concentration of the agents should be stabilized. The stabilization time may vary depending on the physicochemical properties of the CWAs.

7.1.4.4 When the system is stabilized, switch the agent manifold valve into "ON" position and wait 1-2 minutes before starting the sampling procedure.

7.1.4.5 *Start the sampling,* press "START/HOLD" button and the pump starts.

7.1.4.6 After the sampling period has elapsed, the pump stops and the text "SAMPLE OVER" will be appeared on the screen.

7.1.4.7 Switch the agent manifold valve into "OFF" position and remove the PTFE tubing from the vapor generator and then subsequently close the same using screw cap.

7.1.4.8 Remove the sorbent tube from tube fittings and immediately extraction and analysis can be performed. If the sorbent resin is not immediately extracted and analyzed, both ends should be capped carefully with plastic caps and wrap in parafilm for storage or transportation.

7.1.4.9 Attach a new sorbent tube into the sampling system and same procedure should be adopted in order to get the reproducibility and consistency in the concentration of generated live CWAs.

NOTE — The pump period is the actual running time of the pump. If intermittent sampling is not desired, set the pump period to equal the sampling period. If pump period time is less than sampling period, the pump will automatically calculate and control on/off cycling to complete the pump run time during the sampling period.

7.1.5 *Equipments/ Accessories for Sample Preparation*

7.1.5.1 *Extraction solvents (High Performance Liquid Chromatography (HPLC) grade).*

7.1.5.2 *Calibrants for calibration standard preparation*, at least 98 percent purity.

7.1.5.3 *Calibrated micropipettes with tips.*

7.1.5.4 *Calibrated glassware.*

7.1.5.5 *Calibrated weighing microbalance.*

7.1.5.6 *Calibrated microlitre syringe.*

7.1.6 *Preparation of Sample and Blank*

7.1.6.1 Sorbent tube contains 2 beds of adsorbent material, one is having large bed length and another is having small bed length. The purpose of small bed length is to observe any possible breakthrough of CWA from large bed section due to saturation. In case if any CWA will come in small bed, it reflects the adsorption of CWA in large bed section is saturated and subsequently another sorbent tube should be added in series.

7.1.6.2 Pipette out 1.0 ml of appropriate solvent having purity $\geq$ 99.8 percent, into a septum vial of suitable capacity and cap the vial immediately in order to reduce the evaporation of solvents. Take the sorbent tube containing CWA vapor sample and then remove the glass wool and discard it. Open the vial and transfer the large bed length of sorbent into the desorption solvent and re-cap the vial.

NOTE — Complete transfer of sorbent should be ensured while transferring the material in to the solvent containing vial.

7.1.6.3 Agitate the capped CWA vapor sample vial over a period of 15 min to ensure desorption of adsorbed CWA vapor in solvent. Repeat the same procedure for 3 times in order to get maximum extraction efficiency.

7.1.6.4 Repeat the same procedure for second bed of adsorbent tube using a different vial.

7.1.6.5 Desorb the blank sample (sample does not contain CWA) in the same way as it is done in case of CWA vapor containing samples.

7.1.7 *Preparation of Calibration Standards*

7.1.7.1 Prepare multiple points standards to cover the range of applicability.

7.1.7.2 In air concentration (mg/m^3), this range will vary with the relevant exposure limit. With a limit value of 0.05 + 0.005 mg/m^3 and 0.5 + 0.05 mg/m^3, a 10 L air volume sample collected and desorbed in 1 ml will result in a solution of 0.0005 mg/ml and 0.005 mg/ml respectively. To cover a typical range of 0.1-2 times the limit value, solutions in the range 0.00005-0.001 and 0.0005-0.01mg/ml respectively will be needed.

7.1.7.3 Standard solutions of the respective CWA in the elution solvent may be prepared, using either a calibrated micro-syringe or pipette, by adding standard CWA and this will be denoted as first solution. Further standard solutions to cover the range of interest can be prepared by serial dilution of the first solution. The concentration range of the standard solutions should exceed the concentration range of the desorbed CWA samples. For each calibration fresh standard solutions of CWA should be made.

7.1.7.4 A fixed amount of internal standard should be added in the all CWA prepared samples (including standard and testing samples) before the analysis to avoid the manual errors.

7.2 Sampling of HCN/Phosgene Vapors

7.2.1 *Equipments and Apparatus*, apparatus for sampling of HCN/Phosgene gas comprised the following components:

7.2.1.1 *Flow meter*

7.2.1.2 *Detector housing unit*

7.2.1.3 *RH meter*

7.2.1.4 *Stop watch*

7.2.2 *Procedure for HCN/ Phosgene gas Sampling*

7.2.2.1 The sample of generated gas shall be passed from calibrated flow meter/mass flow controller.

7.2.2.2 The measurement/verification of generated concentration shall be determined only after attaining the required specified RH.

7.2.2.3 A sample of the dilution air is taken at a constant flow-rate near the ambient air inlet.

7.2.2.4 Flow control valves and flow-meters are calibrated in order to obtain the flow rates required for sampling.

7.2.2.5 Quick fastening gas-tight connections may be used between the three-way valves/solenoid valve and the sampling point.

7.2.2.6 Detector shall be place in detector housing unit. This unit shall be free from contaminants.

7.2.2.7 After stabilization of required concentration, the response of detector shall be verified intermittently during the challenging of detectors.

8 METHOD FOR QUANTIFICATION OF GENERATED CWA

8.1 Quantification of Nerve/Blistering Agent

A measured volume of sample air is drawn through sorbent tubes. The collected vapor shall be desorbed by a solvent, and the solution is analysed with a gas chromatograph equipped with a mass spectrometer (GC-MS). A calibration plot shall be made for quantification of respective CWA.

8.1.1 *Calibration Plot using GC-MS Analysis*

8.1.1.1 Standard solutions of GB, GF, GA, GD, VX and HD, L in appropriate solvent were prepared in the concentration range 0.050-1.00 µg/ml and 0.50-10.00 µg/ml, respectively.

8.1.1.2 Inject a 0.20-0.50 µl volume of each standard solution mixed with internal standard into GC-MS in Selected Ion Monitoring (SIM) mode analysis.

8.1.1.3 Prepare a calibration graph by plotting areas counts of the CWA peaks corrected for blank levels on the vertical scale against the concentration of the CWA, in µg/ml, in the injected aliquot of the calibration solutions as specified in Table 4.

Table 4 Concentration Range for Calibrations

(*Clause* 8.1.1.3)

Sl No.	Agents	Calibration Range µg/ml	Ion Chromatogram M/Z
(1)	(2)	(3)	(4)
i)	Tabun (GA)	0.05-1	162,43
ii)	Soman (GD)	0.05-1	99,126
iii)	VX	0.05-1	114
iv)	Sarin (GB)	0.05-1	99
v)	Cyclosarin (GF)	0.05-1	99
vi)	Sulphur mustard (HD)	0.5-10	109
vii)	Lewisite (L)	0.5-10	145

8.1.2 *Quantification of Nerve and Blister Agent Vapors*

Calibrated GC-MS shall be used for the determining the challenge concentration of CWA.

8.1.2.1 Make a known conc. range of CWA in order to make standard calibration plot. Add internal standard (IS) of known concentration in each known conc. of CWA in order to avoid human/manual error.

8.1.2.2 Inject CWA solutions with internal standard of known concentrations (one sample shall be injected in triplicate manner in order to get reproducible results) into GC-MS, note down the ratio of peak area of respective CWA and internal standard for every injection and take average for each of the concentrations.

8.1.2.3 Plot standard calibration curve using ratio of average peak area of different concentrations against CWA concentration in µg.

8.1.2.4 Now inject the extracted test sample spiked with internal standard of known concentration, one sample shall be injected 3 to 4 times in order to get reproducible results into GC-MS, note down the ratio peak area for every injection and take average for each of the concentrations and determine concentration of CWA using standard calibration plot.

8.1.3 *Nerve and Blister Agent Samples Analysis*

8.1.3.1 Inject the fixed volume of extracted test sample (same volume injected for standards) into the gas chromatograph. Repeated injection up to 6 times carried out in order to measure standard deviation and concentration of test samples (desorbed sample) can be calculated using standard calibration graph.

8.1.3.2 Analyze the blank sample and the extracted samples with respect to standard calibration graph. If the test samples concentration falls beyond the upper limit of calibration plot, dilute the sample solutions with same solvent to bring the concentration back within the calibration range.

8.1.3.3 Repeat the analysis and record the dilution factor.

8.1.4 *Vapor Concentration Calculations for Nerve and Blister Agent*

Using the syringe, the syringe pump and the rotameter parameters as well as taking advantage of the physical and chemical characteristics of the compound of interest, it is possible to calculate a desired concentration of a vapor (C_{FINAL}) using the following formula:

$$C_{FINAL}\ (\text{mg/m}^3) = [(F_{SYR} \times 1000 \times d_{COMPD.} \times A\text{-\%}) / (F_{AIR} \times 60 \times 100)$$

where

F_{SYR} = Injection rate of the compound from the syringe pump, in µl/h;

d_{COMPD} = Compound density, in g/cm^3 at (27 ± 2) °C;

A = Percent is assay (that is, purity-percent) of the compound, usually quite close to 100 percent;

F_{AIR} = Sum of air flow through rotameters R1 and R2 (lpm);

60 = conversion constant for l/min to l/h; and

100 = conversion constant for percent-value to decimal value).

The desired concentration can also be stated in ppm using the following formula:

$$C_{FINAL}\ (\text{ppm}) = [C_{FINAL}\ (\text{mg/m}^3) \times 24.46] / M$$

where

24.46 = the molar volume (dm^3/mol) of ideal gas, calculated from V/n = RT/P,

T = 298.15 K (25 °C) and P = 101.325 kPa, and

M = the compound molecular mass (g/mol).

8.1.5 *Quantitation of Test Nerve and Blister Agent Samples*

Calculate the weight, in µg, of respective agent in the sample by using the calibration graph prepared for the standard solutions. Also calculate the conc. of CWA in the blank sample (sample without CWAs)

$$C\ (\mathrm{mg/m^3}) = (M_L + M_S - M_{blank}) / D \times V$$

where

C = concentration of analyte, in air (mg/m^3);

M_L = concentraion (µg) of CWA in large bed section;

M_S = concentration (µg) of CWA in small bed section;

M_{blank} = concentration (µg) of CWA in blank sample;

D = extraction efficiency, as read from the extraction efficiency curve; and

V = volume of air sampled (l).

8.2 Quantification of HCN/Phosgene

The quantitation of generated HCN and phosgene gas at the challenge point of CWAD is directly confirmed using calibrated electrochemical/metal oxide HCN detector and photo ionization (PID)/electrochemical detector, respectively by multiplying response factor (in case of PID) if any. Before challenging detector, concentration determination shall be carried out.

9 TESTING OF DETECTOR AT VARIOUS TEMPERATURE CONDITIONS

Performance evaluation of chemical detector shall be conducted at ambient, sub-ambient and above ambient conditions by the following procedures.

9.1 Testing at Sub-ambient Temperature (from-10 to -20 °C)

9.1.1 Place the detectors in environment chamber at (from – 10 to – 20 °C) and store them for 4 h of time as per ATP (accepted test procedure)/trial directive.

9.1.2 After conditioning, the detector will be kept in testing chamber in switched ON mode.

9.1.3 Prior to switch on the detector, it shall be flushed by the clean air for 20 min.

9.1.4 Desired concentration of agent vapors shall be generated followed by its stabilization.

9.1.5 Determine the concentration of agent by GC-MS method (nerve and blister agent). For the confirmation of HCN concentration online detector will be used.

9.1.6 Expose the detector for at least 60 s to clean air with the same condition as going to be challenged with the agent.

9.1.7 Expose the detector to the agent at t = 0 sec and response time measurement will be started.

9.1.8 The response time and the readout of the detector will be recorded on the basis of audio and visual alarms which shall be stable.

9.1.9 The maximum exposure time to the detector will be 60 s, if there is no audio and visual alarm up to 60 s, the exposure shall be stopped**.**

9.1.10 Once the detector is exposed to the clean air, the recovery time starts.

9.1.11 Recovery time shall not exceed 3 min (180 s). This shall also be monitored with each exposure.

9.1.12 When the detector alarm goes off, the recovery time shall be recorded.

9.1.13 Each test shall be performed in triplicate.

NOTE —The experiment at sub ambient condition shall be performed at (– 10 to – 20 °C) in environmental chamber. Generation of vapor shall be at ambient temperature and detector challenge shall be carried out in environmental chamber at – 10 to – 20 °C

9.2 Testing at Ambient Temperature (25 ± 2 °C)

9.2.1 Place the detector at ambient temperature and store them for 4 h of time as per ATP/trial directive.

9.2.2 After conditioning, detector shall be switched ON.

9.2.3 Desired concentration of agent vapors shall be generated followed by its stabilization.

9.2.4 Set the required humidity as per ATP/trial directive.

9.2.5 Determination of agent concentration by online methods/detector (if available) or by offline sampling using sorbent tubes followed by GC-MS analysis.

9.2.6 Expose the detector for at least 60 s to clean air with the same condition as the challenge with the agent.

9.2.7 Expose the detector to the agent (at t = 0) and response time measurement shall be started.

9.2.8 The response time and the readout of the detector will be recorded on the basis of audio and visual alarms which shall be stable.

9.2.9 The maximum exposure time to the detector shall be 60 s, if there is no audio and visual alarm up to 60 s, the exposure shall be stopped.

9.2.10 Once the detector is exposed to the clean air, the recovery time starts.

9.2.11 Recovery time shall not exceed 3 min (180 s). This is also monitored with each exposure.

9.2.12 When the detector alarm goes off, the recovery time shall be recorded.

9.2.13 Each test shall be performed in triplicate.

9.2.14 Repeat the test procedure with other humidity (*see* **8.2.4**).

NOTE — The experiment at ambient condition shall be performed at 25 ± 2 °C in environmental chamber. Vapor generation and detector challenge shall be carried out in environmental chamber.

9.3 Testing at Above Ambient Temperature (from + 42 to + 45 °C)

9.3.1 Place the detector in environment chamber at (+ 42 to + 45 °C) and store them for a 4 h of time as per ATP/trial directive.

9.3.2 Desired concentration of agent vapors shall be generated followed by its stabilization.

9.3.3 Determination of agent concentration by online methods/detector (if available) or by offline sampling using sorbent tubes followed by GC-MS analysis.

9.3.4 As per ATP/trial directive, conditioning of challenge detector shall be performed. After completion, the detector shall be taken out from the environmental chamber and switched ON.

9.3.5 Expose the detector for at least 60 s to clean air with the same condition as going to be challenged with the agent.

9.3.6 Expose the detector to the agent (at t = 0) and response time measurement shall be started.

9.3.7 The response time and the readout of the detector shall be recorded on the basis of audio and visual alarms which shall be stable.

9.3.8 The maximum exposure time to the detector will be 60 s, if there is no audio and visual alarm up to 60 s, the exposure shall be stopped.

9.3.9 Once the detector is exposed to the clean air, the recovery time starts.

9.3.10 Recovery time shall not exceed 3 min (180 s). This is also monitored with each exposure.

9.3.11 When the detector alarm goes off, the recovery time shall be recorded.

9.3.12 Each test shall be performed in triplicate.

NOTE — The experiment at above ambient condition shall be performed (+ 42 to + 45 °C) in environmental chamber. Generation of vapor shall be at ambient temperature and detector challenge shall be carried out in environmental chamber.

10 DETECTOR EVALUATION

CWAD will be challenged against the concentration defined for each type of agents in combinations of temperature and RH as specified in Table 5.

11 SATURATION TEST

The equipment is exposed to natural vapor of sulphur mustard (HD) produced by taking 100 µl of neat agent in vial or test tube of size (8 ± 4) cm at (27 ± 5) °C and RH of (50 ± 20) percent.

Than check recovery time is ≤ 3min or not.

12 FALSE ALARM AND INTERFERENCE STUDIES

CWAD may give false positive or false negative alarm. False positive occur if a detector responds when a CWA is not present. False negative when a detector fails to respond to a CWA that is present.

False positive alarms are usually observed when the targeted compound is in the presence of an interferent, which may be a chemical molecularly similar to a CWA, or a substance which may contain elements that are also present in CWA. For example, pesticides containing sulfur or phosphorus would generate a false positive CWA alarm when an FPD-based detector is used.

False negative alarms are more problematic than false positive alarms because the failure to produce an alarm may lead to dangerous situations. The failure of a detector to alarm to a CWA that is present may be due to any number of reasons including operator error, changing environmental conditions, humidity effects, detector malfunction such as software quirks, and the presence of chemical interferents which may mask normal detection capabilities.

The effects of potential interference will be assessed, by challenging the detectors with the pollutants. A representative set of potentially interfering compounds for testing false positive are mentioned in Table 6. The false positive alarm rate should not exceed 10 percent.

Table 5 Detectors Challenged Against CWAs at Various Combinations of Temperature and Humidity

(*Clause* 10)

Sl No	Agent	Concentration (Tolerance + 25%) mg/m^3	Threshold Exposure Response Time Max, (s)	Relative Humidity (percent RH) Range	Temperature (°C)	Recovery Time (s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Nerve agents: Tabun (GA), Sarin (GB), Soman(GD), Cyclosarin (GF) and VX	0.05	≤ 60	15 ± 5 percent, 50 ± 5 percent and 80 ± 5 percent	25 ± 2 °C	< 180
ii)	Nerve agents: Tabun (GA), Sarin (GB), Soman(GD), Cyclosarin (GF) and VX	0.05	≤ 60	*see* NOTE	Between + 42 to + 45 °C	< 180
iii)	Nerve agents: Tabun (GA), Sarin (GB), Soman(GD), Cyclosarin (GF)	0.05	≤ 60	*see* NOTE	Between – 10 to – 20 °C	< 180
iv)	Blister agents: Sulphur mustard (HD) and Lewisite(L)	0.5	≤ 60	15 ± 5 percent 50 ± 5 percent and 80 ± 5 percent	25 ± 2 °C	< 180
v)	Blister agents: Sulphur mustard (HD) and Lewisite(L)	0.5	≤ 60	*see* NOTE	Between + 42 to + 45 °C	< 180
vi)	Choking agents: Phosgene (CG)	20	≤ 60	15 ± 5 percent 50 ± 5 percent	25 ± 2 °C,	< 180
vii)	Choking agents: Phosgene (CG)	20	≤ 60	*see* NOTE	Between + 42 to + 45 °C	< 180
viii)	Choking agents: Phosgene (CG)	20	≤ 60	*see* NOTE	Between – 10 to – 20 °C	< 180
ix)	Blood agents (AC): Hydrogen cyanide(HCN)	20	≤ 60	15 ± 5 percent 50 ± 5 percent and 80 ± 5 percent	25 ± 2 °C	< 180
x	Blood agents (AC): Hydrogen cyanide(HCN)	20	≤ 60	*see* NOTE	Between +42 to +45 °C	< 180
xi)	Blood agents(AC): Hydrogen cyanide(HCN)	20	≤ 60	*see* NOTE	Between – 10 to – 20 °C	< 180

NOTE — RH will not be maintained externally, it will be recorded as such in the given temperature in the test chamber.

Table 6 List of Interferents

(*Clause* 12)

Sl No.	**Category**	**Interferents**
(1)	(2)	(3)
i)	Category 1 vapor and burning/exhaust	Diesel, kerosene, petrol and vehicle exhaust
ii)	Category 2	Burning tire, menthol and cigarette
ii)	Category 3	Methanol/ethanol, bleach, CW decontamination solutions (DS2)

NOTE — One interferent at a time shall be used to check the false alarm.

12.1 Interferents Test Method

Preferably, fumes of interference agents shall be produced in the open air environment. Each detector unit shall be exposed at a certain distance (0.5-2 meter) (distance based on wind speed and the nature of dissemination of the interferents) for 60 s to each interferent and three consecutive trials shall be recorded. The system should be clear down time at least 3 min. The laboratory tests for the interferents such as kerosene, petrol, diesel, methanol and ethanol shall be conducted in laboratory. Each detector unit shall be tested against the headspace concentrations of vapors. Air stream carries the headspace vapor of the substance by sweeping it over the liquid in a tube or through the liquid in a bubbler to prepare the interferents gas mixture of sufficient volume in air. Each detector unit shall be exposed for 60 s to each interferents gas mixture and three consecutive trials shall be recorded. Testing shall continue with the next challenge after the detector was completely recovered in 180 s from prior exposure.

13 TEST REPORT

A sample format for the reporting of the testing of CWADs are given in Annex A.

ANNEX A

(*Clause* 13)

1.Title………

2. Reference letter ………………………………………………………………………..………………………

3. Equipment under evaluation with serial number……………………………..……………..……..................

4. Test performed by……………………………………………………………………………...............................

5. Test witnessed by………………………………………………………………………………………………

6. Period of testing...

7. No. of pages………………………………………………………………………….............................

8. Report prepared by…………………………………………………………………..……………...............

9.Report reviewed by……………………………………………………………………………………..

10. Report approved by………………………………………………………………….................................

11. Testing team

11.1 Representative………………………………………………………………………………………

11.2 Representative………………………………………………………………………………………

11.3 Representative………………………………………………………………………………………

11.4 Testing co-ordinators……………………………………………………………………………………

11.5 Testing team………………………………………………………………………………………..

11.6 CWA synthesis………………………………………………………………………………………

11.7 Equipment handling…………………………………………………………………..………………..

11.8 Nerve /blister/blood/choking agent testing…………………………………………………………………

11.9 Data recording………………………………………………………………………...…………..

11.10 Technical facility………………………………………………………………………………...

11.11 Maintenance……………………………………………………………………………………..

12. Introduction……………………………………………………………………………………….……….

13. Testing Facility of Chemical Warfare Agent Detectors against Chemical Warfare Agents (CWAs)……………

………

14. Equipment under evaluation…………………………………………………..……………………...

15. Test plan……………………………………………………………………………..………….

15.1 Room temperature…………………………………………………………………………………..

15.2 Relative humidity………………………………………………………………………………………

15.3 JSQR specified concentration……………………………………………………………………….

15.4 JSQR specified response time…………………………………………………………………....

15.5 JSQR specified recovery time……………………………………………………….…………..

16. Executive Summary of the test

Chemical Warfare Agent (CWAs)	Detector			Measurement Error
	1	2	3	
	Response	Response	Response	

17. Outcome of the test and evaluation ……………………………………………………………………………….......

18. Detailed test report…………………………………………………………………………………………….

18.1 Name of chemical warfare agent…………………………………………………………………..……..

18.2 Observed concentration……………………………………………………………………………………….

18.3 Observed room temperature………………………………………………………………..…………….

18.4 Observed relative humidity………………………………………………………………

Equipment Number :			
Sl No.	Response Time (sec)	Recovery Time(sec)	Remark

19. Any remark…………………………………………………………………………………………………

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Chemical Hazards Sectional Committee, CHD 07

Organization	*Representative(s)*
In Personal Capacity	Shri K. S. Ramprasad (***Chairman***)
Alkali Manufacturers Association of India, Mumbai	Shri K. Srinivasan Shri H. S. Das (*Alternate*)
Bhabha Atomic Research Centre, Mumbai	Ms Garima Singh Shri Nishith Gosh (*Alternate*)
Central Leather Research Institute, Chennai	Dr M. Suriyanarayanan
Centre for Fire, Explosives and Environmental Science, GoI, Min of Def,	Shri S. P. Dobhal Dr Aarti Bhatt (*Alternate*)
Central Food Technological Research Institute, Mysore	Dr Dandamudi Usharani Dr Prasanna Vasu (*Alternate*)
Century Rayon,Thane	Dr.Sandeep R. Naik
Crop Care Federation of India, New Delhi	Mr P. N. Karlekar Dr J. C. Majumdar (*Alternate*)
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Department of Space(ISRO), Bengaluru	Shri Muraleekrishnan R. Ms Lakshmi VW (*Alternate*)
Directorate General Factory Advice Service & Labour Institutes, Mumbai	Shri H. M. Bhandari Shri P. G. Satpute (*Alternate*)
Defence Research and Establishment, (DRDO), Gwalior	Dr Prabhat Garg DrVirendra Vikram Singh (*Alternate*)
Hindustan Unilever Limited, Mumbai	Shri Sanjay Harlaka Shri Rakesh Wadalkar (*Alternate*)
Gas Industries Association	Shri Sunil Kher Shri Anoop Tandon (*Alternate*)
Indian Chemical Council, Mumbai	Dr C. Nandi Dr Rakesh Kumar (*Alternate*)
Indira Gandhi Centre for Atomic Research, Kalpakkam	Dr K. K. Satpathy
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Indian Institute of Toxicology Research, Lucknow	Dr D. K. Patel Dr Sheelendra Pratap Singh (*Alternate*)
Institute of Chemical Technology, Mumbai	Prof Dr G. D. Yadav Dr B. M. Bhanage (*Alternate*)
In Personal Capacity	Shri Vipin Doshi

Organization	*Representative(s)*
Ministry of Environment and Forest, New Delhi	Shri Ved Prakash Mishra Dr Dinesh Runiwal (*Alternate*)
National Chemical Laboratory, Pune	Dr Vijay V. Bokade Dr M. Muthukrishnan (*Alternate*)
National Institute of Occupational Health, Ahmedabad	Dr B. Ravichandran
National Safety Council, Navi Mumbai	Shri A. Y. Sundkar Shri K. D. Patil (*Alternate*)
Oil Industry Safety Directorate (Min of Pet & Natural Gas), Delhi	Shri Devendar M. Mahajan
Pesticides Manufacturer and Formulators Association of India	Dr Archana Kumari Dr Sandip Singh (*Alternate*)
Petroleum and Explosives Safety Organisation, Nagpur	Shri M. K. Jhala Dr Yogesh Khare (*Alternate*)
Reliance Industries Limited, Mumbai	Ms Geeta Singh ShriArvind N. Kumar (*Alternate*)
Safety Appliances Manufacturers Association, Mumbai	Shri Mohammad Shri Devang Mehta (*Alternate*)
Shriram Institute for Industrial Research, Delhi	Dr Jagdish Kumar Dr Deep Shankar Chatterjee (*Alternate*)
Tata Chemicals Ltd, Mithapur, Distt, Jamnagar	Shri Snehashish A. Chakraborty Shri D. K. Thakur (*Alternate*)
In personal capacity (*I-4/2/6, Parijat C H S, Spaghetti, Sector 15, Kharghar, Navi Mumbai, 410210*)	Shri S. Soundararajan
National Institute of Technology, Thrichi	Prof S. P. Sivapirakasam Dr Sreejith Mohan (*Alternate*)
BIS Director General	Shri Ajay K Lal, Scientist 'E' and Head (CHD) [Representing Director General (*Ex-officio*)]

Member Secretary

Ms Shubhanjali Umrao
Scientist 'B' (CHD), BIS

(*Continued from second cover*)

In the preparation of this standard, considerable assistance has been derived from Joint Service Qualitative Requirement (JSQR) for CAM: 6665-008 : 2008 (Revised in 2018) and for ACADA: 66657-007: 2008 (Revised in 2018), published by the Inter Services Equipment Policy Committee, Directorate of Standardization, Department of Defense Production.

The composition of the Committee, responsible for the formulation of this standard is given at Annex B.

In reporting the result of a test or analysis made in accordance with this standard, the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’.

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices: *Telephones*

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg
NEW DELHI 110002 — 2323 7617, 2323 3841

Eastern : 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi
KOLKATA 700054 — 2337 8499, 2337 8561, 2337 8626, 2337 9120

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg
CHANDIGARH 160019 — 265 0206, 265 0290

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113 — 2254 1216, 2254 1442, 2254 2519, 2254 2315

Western : Manakalaya, E9 MIDC, Marol, Andheri (East)
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